Third Semester and Master's Thesis Ideas 2019

M.Sc. in Civil and Structural Engineering

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Edited by Johan Clausen

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June 2019

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M.Sc. in Civil and Structural Engineering: Third Semester and Master Projects Ideas

The following pages contain a list of project ideas proposed by the scientific staff at the Department of Civil Engineering, Aalborg University, and a number of companies. The project ideas in this catalogue may form the basis for long and short master projects as well as regular 3rd semester projects at the M.Sc. programme in Civil and Structural Engineering. On some of the project proposals it is stated which type of project the proposal is suitable for. For the rest of the proposals this question should be discussed with the potential supervisor.

Each project description provides a brief overview of the purpose as well as the main activities. Further, a weighting between theoretical analysis, experimental work and computer modelling has been proposed. Usually, this weighting can be changed slightly in accordance with the wishes of the students. The contact persons listed will usually act as supervisors. Questions regarding details about each proposed project should be directed at the contact persons. The contact details can be found via a person search on the university home page. Furthermore, students' own ideas for projects are encouraged and may be discussed with a potential supervisor. In this aspect the proposals in this catalogue can reveal the expertises and research areas of the different supervisors.

Many private engineering companies have a homepage on which they state that they would like to collaborate with students on a master project. Find out more on the individual company home pages.

The preferred group size for master projects is two or three students. In the interest of students as well as supervisors, single-student projects are generally not recommended. In a short third semester project the recommended minimum group size is three students, some supervisors may require more.

At the third master semester, the students have the option of doing a company stay. It is important to realise that this is not a traditional internship, but rather a third semester project carried out in cooperation with a private or public company. An example of a successful subject for such a company stay is also given in the last page of the present catalogue. The student is not allowed to receive a salary from the company if the student also receives SU.

A final remark about master projects: A signed thesis contract must be handed to your study secretary at latest October 1st for long master projects and March 1st for short master projects. The contract must contain information about the project, in particular regarding the educational goals. These must be defined in accordance with the Master Curriculum (danish: Studieordningen) for the M.Sc. Programme in Civil and Structural Engineering at the School of Engineering and Science, Aalborg University. The curriculum can be found at the Study Board of Civil Engineering homepage at https://studieordninger.aau.dk/2018/11/441. The thesis contract

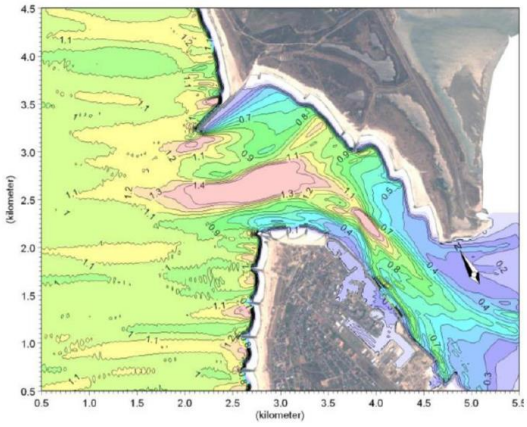
template is the online form available at the homepage of the School of Engineering and Science at https://www.byggeri.aau.dk/Uddannelse/regler-og-formularer/ (In Danish. Choose “Specialekontrakt”) and https://www.civil.aau.dk/education/rules-and-forms/ (In English. Choose “Thesis contract”). The delivery date for the project report will be set by the Study Board. It is usually around June 7 for Master theses. For third semester projects, the thesis contract is not needed.

Aalborg, May 8, 2019 Johan Clausen

Evaluation of closing the Thyborøn Channel to reduce the coastal erosion at down drift beaches along the Danish West Coast

Purpose: Recent research has shown a potential for protecting the Limfjord against storm surges by installing a storm surge barrier in Thyborøn channel. The storm surge barrier can be closed temporarily during storms, which significantly reduce the extreme water levels in the fjord. The high flow velocities into the fjord during storms brings large amount of sediments into the fjord. The present situation is thus that the sediment, which accumulates inside the fjord, is missing in the sediment budget at the west coast, which results in erosion.

The purpose of this project is to use numerical models to analyse whether the storm surge barrier can have a positive effect on the coastal erosion at down drift beaches close to Thyborøn channel, since the flow into the fjord will be much less and thus a much smaller part of the long-shore sediment transport at the west coast is expected to enter into the Limfjord. For the study, there is an opportunity for cooperation with the Danish Coastal Authority.



Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

- Evaluation of the processes leading to coastal erosion near the Thyborøn channel
- Numerical modelling of the influence of closing Thyborøn channel during storm on the coastal erosion at neighbouring beaches

Contact persons: Jørgen Quvang Harck Nørgaard, Thomas Lykke Andersen

Theory: ☒☒☐ Experimental work: ☐☐☐ Computer modelling: ☒☒☒
Suitable project type(s): 3rd sem ☐ short master: ☒ Long master ☒

Wave climate at the Nissum Bredning test site

Purpose: The purpose of the project is to define the wave climate at the Nissum Bredning test site. The test site is located south west from Aalborg and is run by DanWEC in close collaboration with AAU. The test site is equipped with a network of pressure sensors to measure the surface elevation and a wind sensor, giving both speed and direction of the wind.

The Nissum Bredning is situated in the western Limfjord at the Danish North Sea coast. Predominant west winds make this location suitable for testing scaled wave energy devices in real marine conditions. In order to effectively design the machine for a particular location, detailed wave conditions are required. The network of pressure sensors enables the establishment of the wave climate including directionality of the waves, which is valuable information for future developer interested in testing their device at the test site.

Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

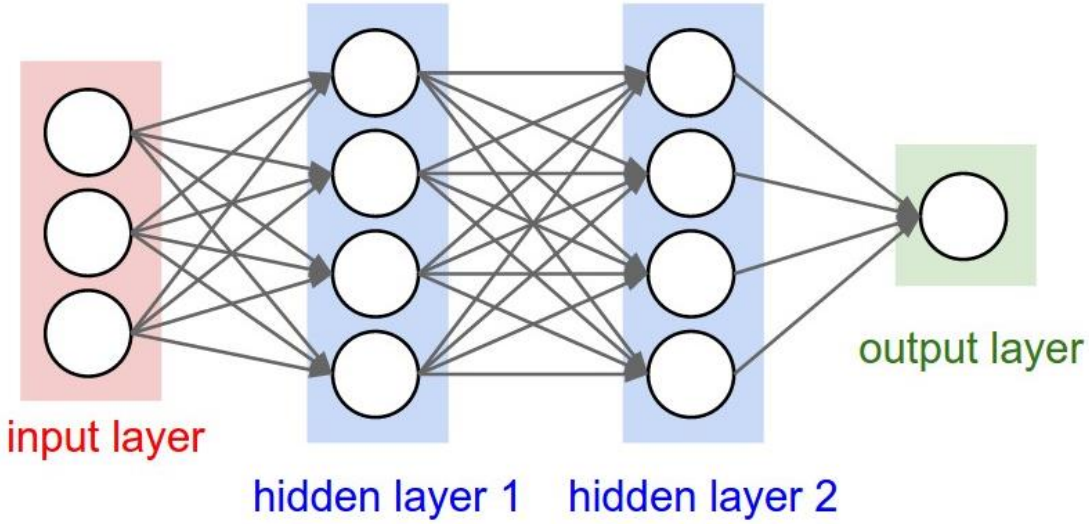
- Optimisation of the network sensor and gathering of data.
- Establishment of the wave climate at the test site based on the measurements including data quality control.
- Establishment of online monitoring of the wave climate

Contact persons: Amélie Têtu, Morten Kramer

Theory: ☒☐☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☐

Forecast of wave conditions at DanWEC test site

Purpose: Forecast of wave conditions is of primordial importance for planning installation, operation and maintenance of wave energy converters, which can account for more than 25% of the cost of energy. At DanWEC, the Danish test center for wave energy, a forecast model has been developed in collaboration with DHI group through an ongoing project. This model is run at DHI and is rendered available for DanWEC during the current project life time. In order to ensure that DanWEC has a reliable tool for predicting the wave climate at the test site, a forecast model needs to be developed. Autoregressive model or machine learning model are examples of models that could be developed for this purpose.



Main activities:

- Literature survey to give an overview of the different models that can be used for forecasting wave climate.
- Establishment of the model for forecasting wave climate at the test site.
- Establishment of online display of the wave climate forecast

The project will be connected to ongoing research projects.

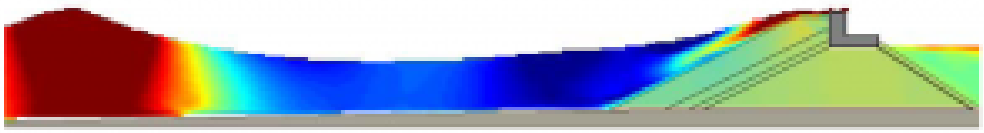
Contact persons: Amélie Têtu, Jens Peter Kofoed

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☐ **short master:** ☐ **Long master** ☒

Wave height distributions and wave attack on coastal protection structures in highly nonlinear deep and depth limited irregular wave conditions

Purpose: Most state of art design formulae for estimation of influence from wave attack on coastal protection structures (stability of superstructures, stability of armour layer, wave overtopping, etc.) are based on relatively linear wave conditions. However, many coastal protections structures are located in relatively shallow water wave conditions with long waves, i.e. non-linear wave conditions.

Recent research has indicated that the existing design tools might provide unsafe predictions in non-linear wave conditions and moreover existing wave height distributions are seen to underestimate the highest wave heights during a storm. The purpose of this study is to evaluate the influence of wave non-linearity and to derive modifications to existing design formulae and wave height distributions based on physical model tests or numerical models.



Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

- Experimental and/or numerical modelling of wave height distribution in deep and depth limited non-linear wave conditions
- Experimental and/or numerical modelling of wave run-up, wave overtopping, and armour stability on rubble mound breakwaters in non-linear wave conditions
- Experimental and/or numerical modelling of dynamic wave loads on rubble mound breakwater crown walls in non-linear wave conditions

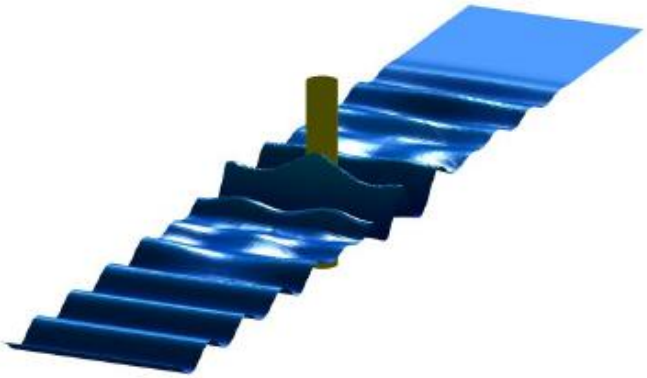
Contact persons: Jørgen Quvang Harck Nørgaard, Thomas Lykke Andersen

Theory: ☒☒☐ Experimental work: ☒☒☐ Computer modelling: ☒☒☐
Suitable project type(s): 3rd sem ☐ short master: ☒ Long master ☒

Wave breaking in a fully nonlinear potential flow spectral element model

Purpose: The purpose is to implement, verify and validate different levels of fidelity in modelling wave breaking in a fully nonlinear potential flow (FNPF) model. The FNPF model is based on the based on the spectral element method (SEM) – an unstructured arbitrarily high order numerical model based on sigma-transformed coordinates. The use of sigma-transformation makes that wave breaking cannot be naturally handled by the model but needs to be approximated in some way.

In the project different approaches to modelling wave breaking will be tested, initially the eddy viscosity concept and the wave roller concept.



Main activities: The project will contribute to the on-going development of the model and the following activities can be included:

- Study of theoretical breaking models
- Implementation into the numerical code (requires skill in matlab or c++)
- Verification and validation against standard test cases

The project will involve co-operation with external parties (DTU, Denmark and INRIA, France).

Contact person: Claes Eskilsson

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☐ **Long master** ☒

Limiting wave conditions for caissons installation: Developing a design methodology

Purpose: Caisson breakwaters are generally the preferred solution for new marine terminals/ports built in deep water locations. The caisson installation is generally planned to be carried out in the season where sea conditions are relatively calm. The installation of caisson breakwaters is expensive with high daily mobilization cost and with very large specialist equipment. However, due to the locations of these terminals, many are exposed to swell conditions making installation particularly difficult and time consuming. There is no present guidance for designers or contactors with clear methods to determine limiting wave conditions for caisson installing operations. COWI has been involved in several projects where caisson installation challenges were experienced.

The objective of the project is to study the wave-structure hydrodynamic interaction of the caisson in its pre-final stage (during ballasting and immersion), in order to determine the limiting wave conditions for the caisson installation. The project focuses on the hydrodynamic characteristics in the prefinal stage where the caisson is still acting as a large floating structure.

Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

- wave-structure interaction modelling for large floating structures
- data analysis and assessment for different caisson size/weight and wave conditions
- developing a general design methodology for limiting wave conditions for caisson installation using artificial intelligence or other advanced methods.
- Experimental verification of the developed model (in case of long master thesis).

Contact persons: Thomas Lykke Andersen

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Wave loads on concrete caisson during installation

Purpose: The purpose is to estimate the wave loads on a concrete caisson during installation where it is filled with water and before ballast material is installed. Under such situation there will be wave induced pressure on also the inner walls. COWI has estimated that omission of these pressures may lead to a significant contribution to the overall fatigue loads on the caisson walls. This project aims at studying the wave induced loads on the wall of the caisson (numerically and/or through model tests) and is carried out in close cooperation with COWI and actual projects.

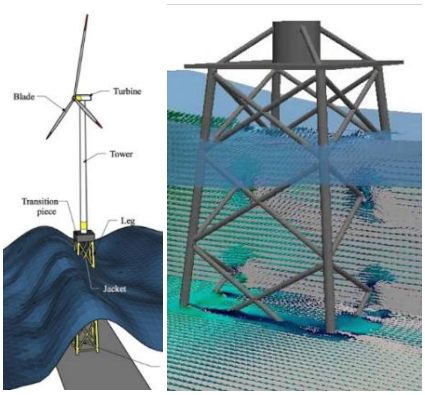
Main activities: The aim is to develop a simplified model for the loads on the caisson walls before the caisson is ballasted. In order to develop and calibrate such model CFD modelling and/or experimental model tests should be carried out.

Contact persons: Thomas Lykke Andersen, Morten M. Kramer

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

VATTENFALL

Assessment of wave loads on a jacket type of offshore structures



Purpose: To develop a guideline for assessment of wave loads on jacket type substructures for offshore wind applications. The guideline shall indicate how Morison formulation should be used in context of a jacket structure, how to evaluate influence of shadow effects and how to treat non-cylindrical structure elements like i.e. nodes.

Jacket type of foundation is a truss-like supporting structure featuring on one hand a complex topology but which, on the other hand, is composed of simple and considerably slender tubular elements. The latter suggests that a suitable simulation model should be based on cylindrical elements with broad application of Morison formulation. One of the assumption of the formulation is that the wave passes undisturbed through the structure. That is however not completely true as one can imagine that a structure element encountering the wave creates a wake behind which might influence forces at other, not so distant elements. Yet another topic is wave flow around more massive and more irregular structure elements as jacket nodes. Intuitively, the total wave induced force at this part of the structure seems to be larger than a simple summation of loads derived from corresponding parts of adjoining beams.

Main activities: Project will by means of Computational Fluid Dynamics (or similar) investigate flow of an irregular wave across the jacket type object. Investigation shall focus on detecting and evaluating of influence of closely spaced jacket members on the wave flow including massive and irregular elements as jacket nodes. Loads on particular elements in the complex jacket structure are to be evaluated and compared with corresponding loads calculated with the Morison formulation. The project shall suggest a methodology for calibration of Morison formulation depending on geometry and topology of a jacket structure, preferably in an analytical way.

Additionally the project may suggest a setup for a scale test that could be used to confirm both assumptions of numerical simulations and the outcome.

Contact persons: Thomas Lykke Andersen, Dariusz Eichler (Vattenfall)

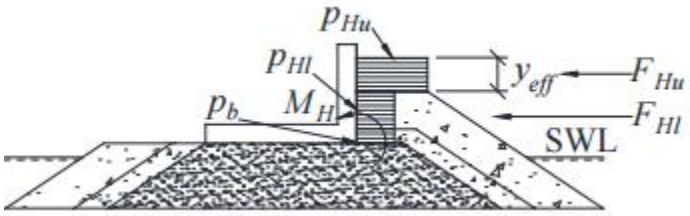
Theory: ☒☒☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

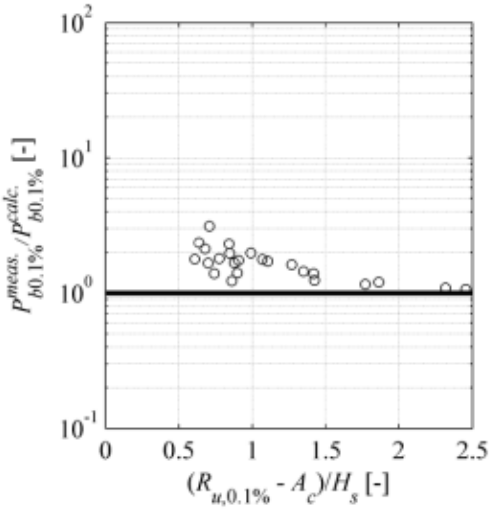
Reanalysis of wave loads on breakwater crown walls

Purpose: The purpose is to extend the formula by Nørgaard et al. (2013) for wave load calculation on breakwater crown walls. The formulae can be extended to include the roughness effect from the armour units. Furthermore, is the prediction of the pressure at the corner (p_b) under-predicted when the wave run-up is equal to or below the crest elevation A_c. Therefore, modifications to the present formula should be performed such that the formula is also valid for low run-up levels.

New tests in the flume at AAU should also be performed if white spots in previous tests are identified.

Contribution: The project can contribute to an on-going PhD study that is working with response of structures exposed to long waves, and the suggested project is a natural extension of this work.





Main activities:

- Extend present formulae to include different armour types and low wave run-up levels

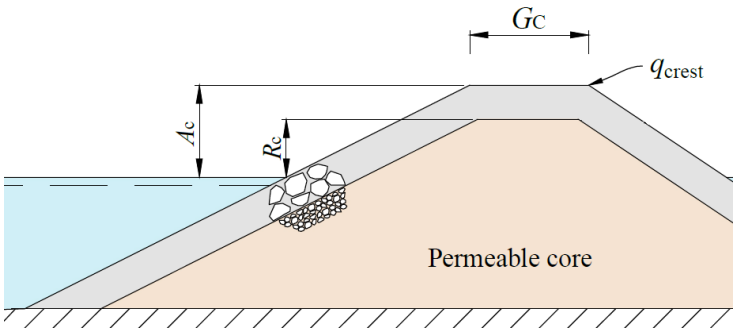
Contact persons: Mads Røge Eldrup, Thomas Lykke Andersen

Theory: ☒☒☒ **Experimental work:** ☒☒☐ **Computer modelling:** ☐☐☐
Suitable project type(s): **3rd sem:** ☐ **short master:** ☒ **Long master:** ☐

Design Tools for Wave Overtopping and Stability Of Rubble Mounds Exposed to Deep and Shallow Water Waves

Purpose: In a recent PhD study, tests with wave overtopping and rock armour stability were performed. In that study, new design formulae were established improving the reliability for estimations for surging waves (long period waves) and highly nonlinear waves (stream function waves). However, there are many white spots not yet investigated. This involves for example the influence of the thickeness and permeability of the different layers. Moreover, the influence of the crest width (Gc) on overtopping of long waves (swells) is a significant white spot in existing design tools.

New physical model tests with wave overtopping and rock armour stability should in the present project be performed in order to investigate the identified white spots. The tests will be carried out in the wave flume at Aalborg University. The present study will lead to new design tools relaveant for coastal engineers worldwide.



Main activities:

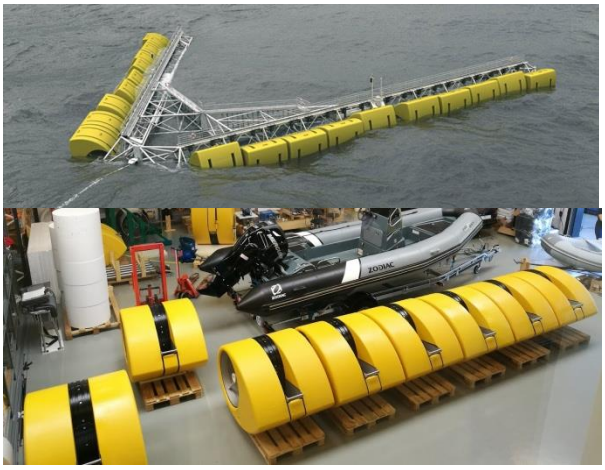
- Litterature study to clarify white spots in existing design formulae
- Experimental modelling to study identified white spots
- Update design formulae based on obtained experimental data

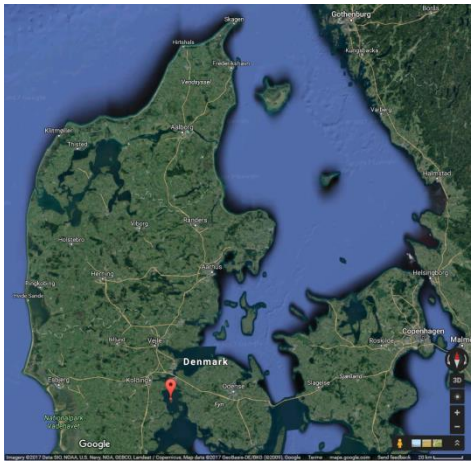
Contact persons: Mads Røge Eldrup, Thomas Lykke Andersen

Theory: ☒☐☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☐☐☐
Suitable project type(s): **3rd sem:** ☐ **short master:** ☒ **Long master:** ☒

Analysis of performances of the Weptos wave energy converter

Purpose: The Weptos wave energy converter (WEC) is an A-shaped floating structure that absorbs wave energy through multiple wave absorbing bodies, the rotors. The prototype was launched in the spring of 2018, with a location in Lillebælt between Jylland and Fyn in Denmark, north of the small island Brandsø at a water depth of 10 m. The prototype with 20 approx. 1 m rotors is equipped with PLC control, a power-take of (PTO) drive train and electrical generators (2x 3 kW PMGs with back-to-back AC/DC/AC inverters). In addition to acquisition of the produced power of the PTO system at different stages of conversion, also the mooring force, the motion of the structure and the position of the opening angle is monitored and recorded continuously. For the characterization of the environmental conditions a TRIAXYS G3 Directional Wave Buoy was deployed. Sufficient data are gathered to enable evaluation of performance of the device and will be used in the current project for the analysis of performances of the Weptos prototype.





Main activities:

- Establishment of a database for the data acquired during the test campaign.
- Performance evaluation in terms of energy production and losses throughout the system.
- Evaluation of the performance of the mooring system. Validation of the initial mooring design.

Contact persons: Amélie Têtu, Jens Peter Kofoed

Theory: ☐☐☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☐

Control of the Weptos wave energy converter

Purpose: The development of the Weptos wave energy converter (WEC) is well under way with a machine being deployed in Lillebælt, Denmark. This system has so far been tested with simple control strategy and could gain in efficiency by developing a suitable control system. This control system will be composed out two parts: the adaption of the opening angle between the legs, which regulated the available incoming wave power, and the damping presented by the electrical generator system.

Main activities: The control system of renewable energy systems is not a new topic. However it has not been optimised yet for this particular application. Therefore first a thorough literature review has to be performed. Based on previous laboratory test results, smart control systems have to be presented. These can then be tested and further improved by performing experimental tests in the wave basin on real laboratory models.

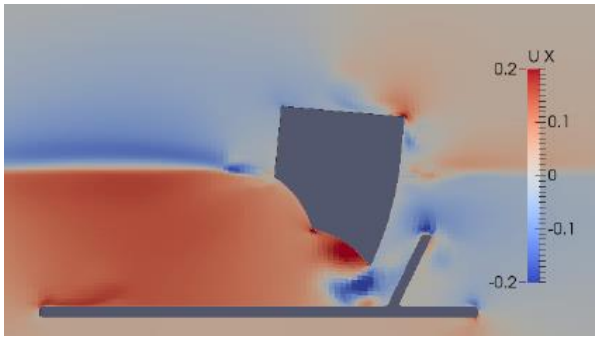
Contact persons: Amélie Têtu, Jens Peter Kofoed

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☐ **short master:** ☐ **Long master** ☒

Simulation of wave energy conversion in a multi-use platform

Purpose: The company Floating Power Plant is developing a combined platform for harvesting wind and wave energy. The wave energy converters (WECs) are designed as pitching devices attached to the hull of the semi-submersible. Together with Floating Power Plant the project will perform detailed wave-body simulations and estimate the wave loads acting on the WEC and semi-submersible.

The wave energy converters are marked in red



www.floatingpowerplant.com

Main activities: The project will apply CFD modelling using the OpenFOAM® software (www.openfoam.com). The main topic relates to the treatment of the mesh motion. The WEC moves in close proximity to the semi-submersible making this a challenging task. Algorithms for the power transformation will be implemented in the OpenFOAM framework to accurately include the forces arising from the power take-off in the simulations. The main outcome of the project will be the forces and restoring moments acting on the WEC.

The calculations can, if wished by the students, be supplemented by laboratory experiments, which can be performed in the wave basin at AAU. The results can be used to validate the CFD calculations.

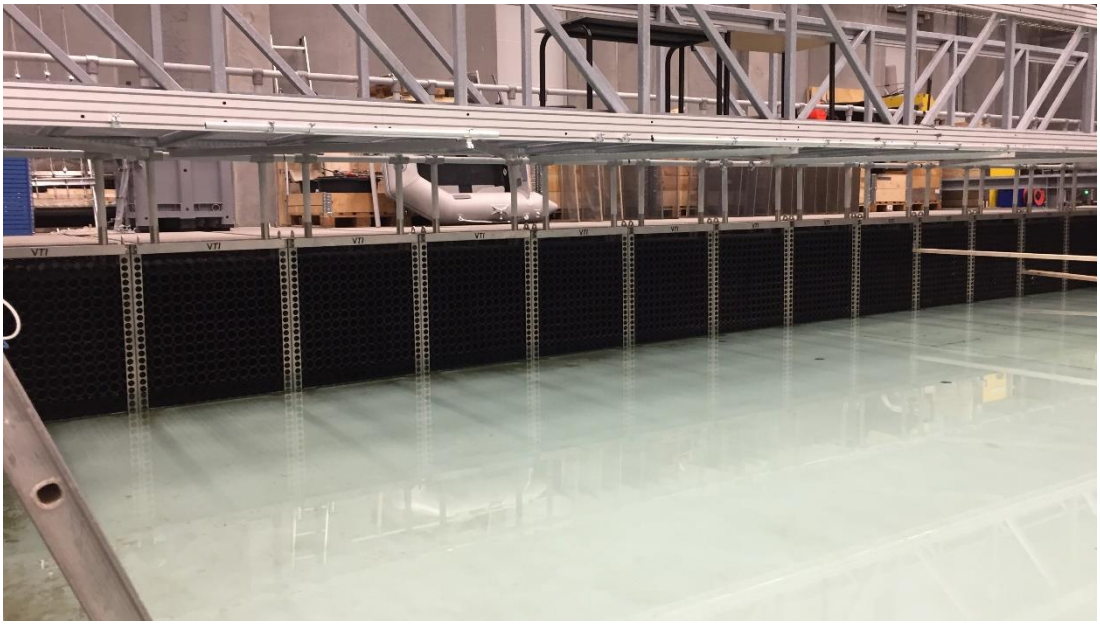
Contact persons: Morten Bech Kramer, Claes Eskilsson

Theory: ☒☐☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☐ **Long master** ☒

Optimisation of passive wave absorbers

Purpose: The purpose is to optimise the current passive absorption system in the new laboratory at Aalborg University. In order to do that, individual plate absorbers are tested with respect to their performance in term of absorption, reflection and transmission properties for different wave conditions. The optimisation is made by performing laboratory tests in the flume and basin. The key objective is to reduce generation of high-frequency waves which occur for the present absorber layout. Configurations of an array with multiple plates are also tested, and a mathematical model is made to predict the performance.

Contribution: Preliminary tests have been performed, but a more in-depth study on the wave condition is wanted. The influence of the wave height, wave period and water depth is wanted.



Main activities:

- Clarify the absorption capability for an array of perforated plates and the influence of different wave heights, wave periods and water depths.
- Experimental study of the reflection coefficient for a passive absorber.

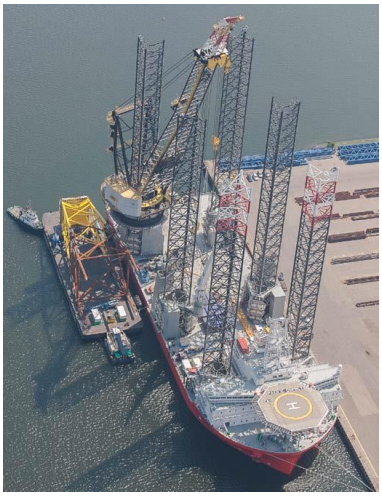
Contact persons: Mads Røge Eldrup, Thomas Lykke Andersen

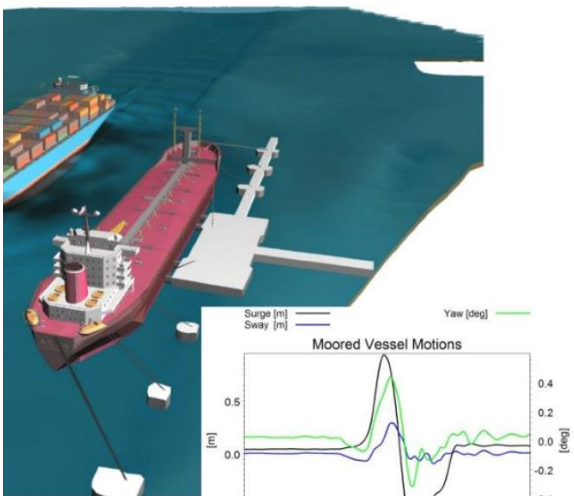
Theory: ☒☐☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☐☐
Suitable project type(s): **3rd sem:** ☐ **short master:** ☒ **Long master:** ☒

Mooring behaviour of vessels in ports

Purpose: The purpose is to make use of a mooring analysis tool within the MIKE 21 MA suite and assess the suitability of the existing design guidelines in PIANC on allowable wave disturbance for assessment of downtime in ports.

A newly featured tool being available in the MIKE21 software toolbox from DHI is supposed to be used/ validated in combination with e.g. physical model tests and/or state of art knowledge for the evaluation of moored vessel response in ports. The tool can be coupled with a Boussinesq model to simulate the floating behaviour of moored vessels in a port. The most used guidelines on "allowable" wave disturbance in ports are relatively primitive and the present project should investigate alternative and more sophisticated methods.





Main activities: The project will contribute to the on-going research and development on the subject and thus the following activities can be included:

- Combined numerical modelling of wave disturbance and floating behaviour of moored ships in a port
- Validation of MIKE 21 MA suite for modelling of moored ship movements

Contact persons: Jørgen Harck Nørgaard, Thomas Lykke Andersen

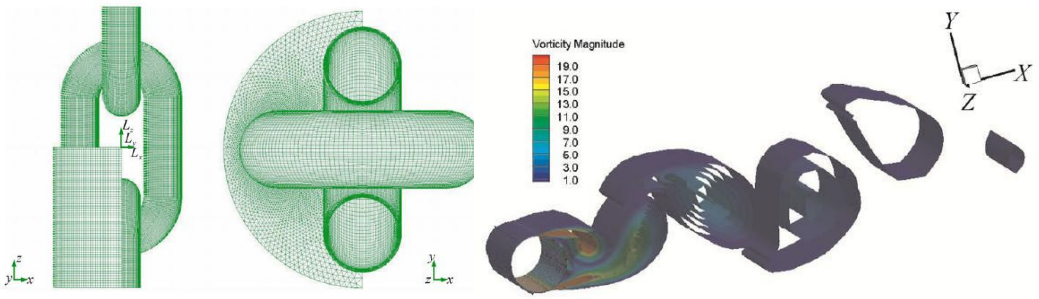
Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☒

CFD study of mooring cables in waves

Purpose:

The goal of this project is to improve the knowledge of what happens when mooring cables move in the water and are subjected to waves, so engineers can better estimate mooring loads. Research carried out at AAU shows that current methods to determine loads on mooring cables, using Morrison's equation, might be inaccurate. We need a better understanding of the physics of turbulence, drag, and inertia of mooring cables.

Is it acceptable to use a single drag and inertia coefficient to model fluid forces along the whole mooring cable? Is it necessary to improve Morisson's equation to properly compute the fluid loads? These are some of the question that we need to investigate. The project will contribute to the on-going research on design methods for mooring systems of wave energy converters.



Images from: Zhengqiang Xu and Shan Huang. "Numerical Investigation of Mooring Line Damping and the Drag Coefficients of Studless Chain Links". J. Marine Sci. Appl. (2014) 13: 76-84
DOI: 10.1007/s11804-014-1235-0

Main activities: We expect the following activities:

- Numerical model of a mooring cable in OpenFOAM
- Simulation of different flow conditions around the mooring cable (uni-directional flow and regular waves)
- Assessment of the importance of drag and inertia phenomena for loads on mooring cables

Contact persons: Claes Eskilsson, Guilherme Paredes

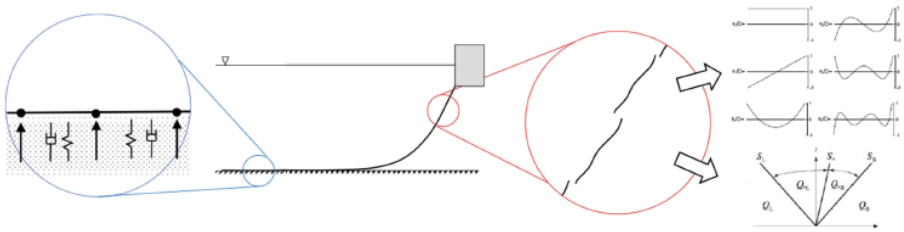
Theory:☒☐☐ Experimental work:☐☐☐ Computer modelling:☒☒☒
Suitable project type(s): 3rd sem☐ short master:☒ Long master:☒

Influence of ground models in mooring cable dynamics

Purpose: MooDy is a mooring cable dynamic solver based on *hp*-adaptive finite element techniques. It has been found that this numerical setting is more sensitive to the applied ground model (acting on the part of the cable lying on the seafloor) than mooring cable codes based on the lumped-mass method. Presently only a bilinear spring-damper ground model acting on the local nodes is implemented. The purpose of this project is twofold:

(i) to test other ground models proposed in the literature

(ii) to investigate a better way to incorporate the ground than directly on the local nodes as this is introducing noise into the higher order discretization.



Main activities: The project will contribute to the on-going development of the model and the following activities can be included:

- Study of used ground models in mooring dynamics codes
- Implementation into the numerical code (requires skill in matlab or c++)
- Estimation of uncertainties introduced by the ground models

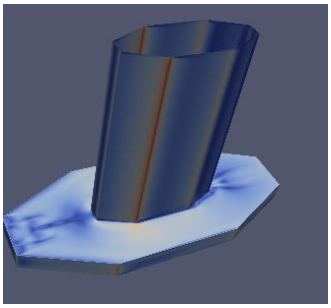
The project will involve co-operation with external parties (Chalmers, Sweden).

Contact persons: Claes Eskilsson, Guilherme Moara Paredes

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☐ **Long master** ☒

Floating platforms for renewable energy

Purpose: The company Floating Power Plant is developing a combined platform for harvesting wind and wave energy. The platform is moored in a single point, a so-called *turret mooring* (picture below on the left) about which it rotates freely 360°. The platform is designed to be facing the waves with optimal wave energy absorption for head-on waves. However, the orientation of the platform is governed by the complex hydrodynamic interaction of currents, wind-waves and swell-waves, which are generally coming from different directions. Together with the private company Floating Power Plant the project will develop new methodologies to calculate the restoring moments in combined waves and currents, and thereby predict the orientation of the platform.



www.floatingpowerplant.com

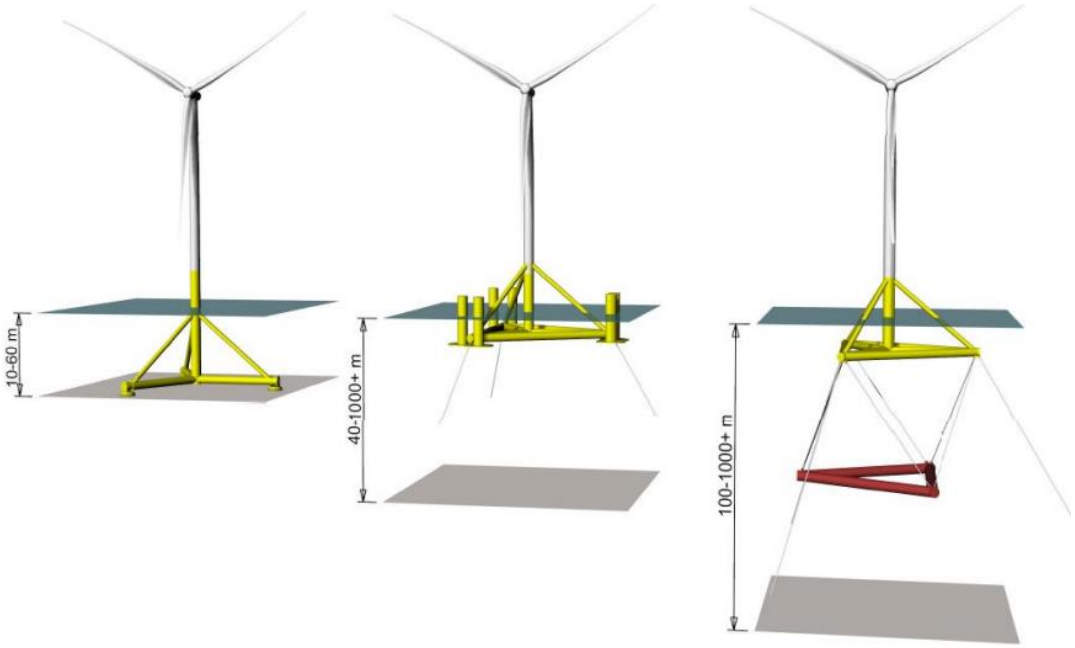
Main activities: The project will investigate the influence of currents and waves on the orientation of the device. A main outcome of the project will be drag coefficients to determine the forces and restoring moments depending on the orientation of the device. The CFD software OpenFOAM® will be extensively used to calculate the coefficients (www.openfoam.com).
The calculations can, if wished by the students, be supplemented by laboratory experiments, which can be performed in the wave basin at AAU. Currents can be applied in the basin and the forces and moments on the platform measured together with the current velocity. The results can be used to validate the drag coefficients by the CFD calculations.

Contact persons: Morten Bech Kramer, Claes Gunnar Eskilsson

Theory: ☒☐☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☐ **Long master** ☒

Next Generation of Offshore Wind Turbine Foundations

Purpose: The offshore wind industry in Northern Europe has seen rapid growth of the last decade. This growth had been greatly assisted by the relatively shallow waters of the North Sea where monopiles have proven to be a cost-effective foundation solution.
Currently AAU is heavily involved in the research and development of the next generation of offshore wind turbines foundations. For countries with deeper waters floating foundations are the only answer, and multiple concepts are already claiming commercial readiness. For shallower waters self-installing bottom-fixed foundations are on the horizon in order to (like the floating counterparts) negate the costly heavy offshore lifting operations currently taking place.
A thesis project within this area can cover one or more of several disciplines: hydrodynamic calculation of stability/wave loading, design of novel mooring systems, structural design of foundations, innovative installation techniques, and many more. The project scope will be defined via discussion with supervisor.



Main activities: Depending on topics chosen the main activities will vary. Numerical modelling will likely form the basis of the project, while comparisons to experimental investigations or analytical solutions are optional.

Possible external collaborations: Depending on project scope/focus:
Stiesdal Offshore Technologies, Siemens Gamesa Renewable Energy, Welcon, Blue Power Partners, DIS/CREADIS.

Contact persons: Morten Thøtt Andersen

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☒

Reliability based planning of inspections of foundations in a large offshore wind farm

Purpose: To develop and demonstrate framework for planning of inspections of wind turbine foundations in a large offshore wind farm. The methodology shall be based on probabilistic approach and allow for determination of inspection schedule for individual foundations from the structure reliability point of view. The framework shall utilise effect of numerous foundations featuring similar design and subject to similar external conditions. The project is proposed by Vattenfall.

Normally foundations are designed in such a way that the inspections are not necessary. This is achieved by selecting relevant safety factors. However, there might occur extraordinary conditions that impose an inspection requirement. This could be on intention, where savings are anticipated by introducing an inspection regime in the design phase and thus allowing for reduction of safety factors. But this could be also due to unforeseen structural integrity issues of a serial character that invalidate design assumptions and where inspections are seen as a risk mitigation measure.
Inspections of offshore structures are relatively expensive and inspecting every foundation at a fixed interval and regardless of findings is impractical. The reliability based approach offers a methodology to plan inspection intervals according to change of structural integrity reliability level and allow for upgrades of reliability should inspection not reveal any failures or damages. Thus intervals can be designed such that reliability level is always kept above an allowable limit.

Main activities:
The main scope of work is to define a framework for planning of inspections of foundations based on probabilistic methodology. The framework shall include a timewise degradation model for reliability of structure integrity, shall utilise stochastic model of inspection quality in terms of failure detection and take advantage of a large number of foundations of the same type and exposed to similar external conditions.
Result of the work shall be demonstrated in form of an inspection plan designed for a specific wind farm optimised according to inspection quality and number of similar foundations.

Options: Include in the model a variability of both designs and external conditions across the wind farm.

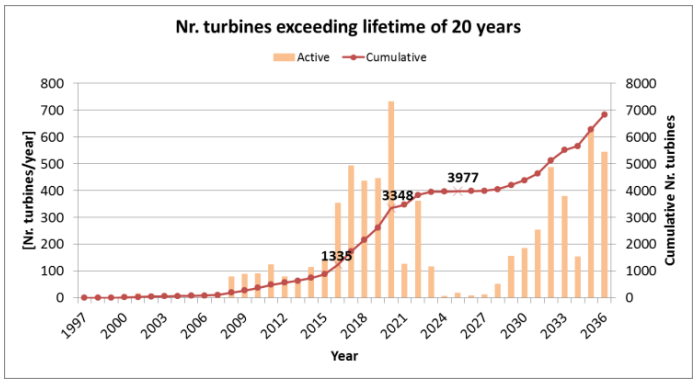
Contact persons: John Dalsgaard Sørensen, Jannie Sønderkær Nielsen

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Life extension for wind turbines

Purpose: The purpose of this project is to contribute to optimal decision making in relation to life extension of ageing wind turbines.

Within the next few years, thousands of wind turbines in Denmark will reach their design life time of 20 years. However, if it can be shown that the risk of structural failure upon continued operation is acceptable, the turbine should be allowed to continue operation. For example, the fatigue life usage can be estimated using load observations or SCADA data. Although not critical for safety, the condition of non-structural component influence expected maintenance costs, and is relevant to consider for profitability. Inspections and testing can also be used to assess the current health of components.



Main activities:

- Literature survey on life extension for wind turbines
- Assessment of fatigue life usage based on data
- Reliability analysis of wind turbines
- Reliability updating using data from tests
- Estimation of maintenance costs

The project will be connected to the ongoing research project LifeWind with participation of industrial partners.

Contact persons: John Dalsgaard Sørensen, Jannie Sønderkær Nielsen,

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Risk-informed operation and maintenance for offshore wind turbines

Purpose: The purpose of this project is to apply risk-based techniques and Bayesian statistical methods for planning of O&M activities in practical applications incl. modelling of costs and risks in connection with O&M for offshore wind turbines.

Costs to operation and maintenance (O&M) of offshore wind turbines are large, typically more than 25% of the cost of energy. The costs consist of planned maintenance and corrective maintenance due to failure of components such as gearboxes, electrical components and blades, due to e.g. wear and fatigue. One main contributor to the high offshore O&M uncertainty and costs is the dependence on weather windows. In other engineering areas such as the offshore oil & gas industry and civil engineering bridges, rational approaches to planning of O&M have been developed. These approaches are based on risk and reliability-based techniques where it is possible to plan rationally future actions based on available information at the time of decision and models for costs and uncertainties.



Main activities:

- Literature survey to give an overview of decision problems and methods for O&M planning
- Development of risk-based decision models and illustrative examples for selected problems e.g.
    - Optimal planning of inspections and maintenance for selected components
    - Combining several types of data for diagnostics using Bayesian methods
    - Short term decisions based on probabilistic weather forecasts

The project will be connected to ongoing research projects and can contain external collaboration.

Contact persons: John Dalsgaard Sørensen, Jannie Sønderkær Nielsen

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Resilience of wind power plants

Purpose: This project aims to develop a computational model for the quantification of resilience of wind energy systems.

Understanding resilience as the ability of a system to sustain, adapt to and recover from events of disturbance, resilience is affected by decisions made on design, operation and maintenance. For Danish wind farms, where natural hazards are not likely, the most severe threat is the combination of human error and system effects. Dependencies across the system make failure events highly correlated, thus one design error could severely affect the system function. Although the wind industry is maturing, the constant pressure for cost reductions drives the designs to the limits, and new issues can appear. To enhance reliable energy supply from wind energy systems, a system perspective is called for. To quantify the resilience, the focus is on the modelling of wind power plants as systems, the assessment of the reliability of these systems, and the modelling of the recovery.

Main activities:

- Literature survey to give an overview of quantitative measures and methods for resilience quantification.
- Development of resilience quantification model incl.
    - Modelling of disruptive events
    - System reliability modelling
    - Adaption and recovery modelling
    - Parameter studies

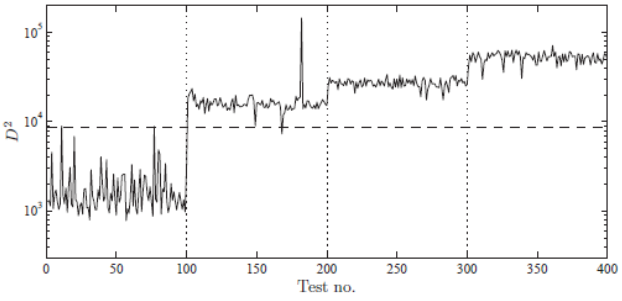
Contact persons: Jannie Sønderkær Nielsen

Theory: ☒☒☐ Experimental work: ☐☐☐ Computer modelling: ☒☒☐
Suitable project type(s): 3rd sem ☒ short master: ☒ Long master ☒

Value of information of structural health monitoring for wind turbine blades

Purpose: The purpose of this project is to quantify the value of information of structural health monitoring for wind turbine blades.

For offshore wind turbines, operation and maintenance costs are large. To reduce the need for expensive blade inspections and unexpected repairs, structural health monitoring (SHM) systems can be used to monitor the condition, for example using vibration-based detection methods. However, SHM systems are not perfect, and impose an extra cost. Therefore, the profitability of SHM should be quantified. This can be done using the concept of value of information (VoI), originating in the Bayesian decision theory, which has gained interest within many areas of civil engineering in the recent years.



Main activities:

- Modelling of the reliability of structural health monitoring
- Formulation of decision models
- Estimation of expected costs and VoI using Bayesian decision analysis
- Sensitivity studies

The project will be made in co-operation with a manufacturer of a structural health monitoring system, Brüel & Kjær Sound & Vibration.

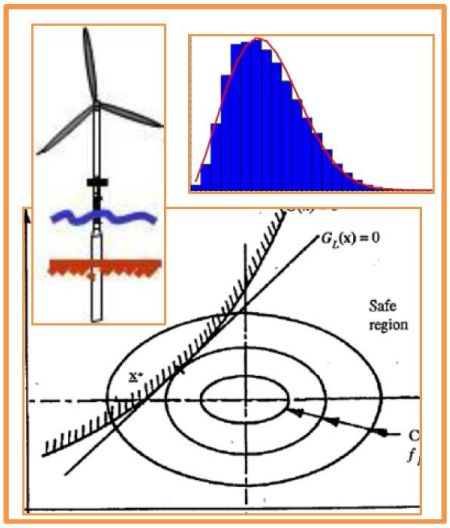
Contact persons: Jannie Sønderkær Nielsen, Martin Ulriksen

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

VATTENFALL

Reliability based design of offshore wind turbine foundation

Purpose: To develop and demonstrate framework for design of an offshore wind turbine foundation with application of probabilistic methods. The suggested methodology shall be able to verify values of safety factors given in present design standards and indicate potentials for reliability based optimisation. The project is proposed by Vattenfall.



State-of-the-art methodology for design of supporting structures is based on prescribed safety factors that are to reflect uncertainty of design parameters such as load and response. Furthermore the safety factors are usually regulated according to the consequences of a potential failure. The design framework presented in standards is built on experience and based on typical design solutions. Whenever a design concept and/or probability profile of design variables deviates from a typical ones considered in standards, the safety factors are challenged and the result can be either over conservative or even unconservative. The former being economically undesired and the latter dangerous as giving false feeling of safety. Technology as well as technical knowledge constantly develop and the design variables can now be described more precisely and specifically depending on the application. This builds a ground for more direct design methods based on stochastic approach and reflecting the real (on the contrary to assumed) nature of design variables. That will definitely allow for designs optimised according to their specific application and a desired risk profile.

Main activities:
The main scope of work is to define a framework for analysis of reliability of design of an offshore WTG foundation. The work shall be based on a deterministic model that is controlled by a defined set of variable parameters. The parameters are to be described in a stochastic way and reflect, to a practical degree, realistic probability distributions of particular design variables. By application of probabilistic methods the framework shall allow for assessment of reliability of the design by means of reliability index or similar. Furthermore, the work should include sensitivity studies and for selected parameters demonstrate influence of their modified stochastic characteristics on the final design.

Options: Yet another challenge is a reliability based optimisation of a design. The work should be concentrated on creating a framework allowing for optimisation of a design based on both cost and reliability.

Contact persons: John Dalsgaard Sørensen, Jannie Sønderkær Nielsen

Theory: ☒☒☐ Experimental work: ☐☐☐ Computer modelling: ☒☒☐
Suitable project type(s): 3rd sem ☒ short master: ☒ Long master ☒

Development of driveability model for piles for offshore wind turbines

A project with COWI

Purpose: An increased focus on renewables in general has ignited a spark in market for offshore wind turbines. The industry has a joint mission to lower the cost of energy from offshore wind turbines to make the solutions more competitive in the open energy market. The installation of piled foundations for offshore wind turbines is today governed by qualified guessing, since soil conditions may vary greatly throughout an offshore wind farm. The ability to predict and complete the driving campaign as effortlessly as possible is more often than not a project deal-breaker.

Up-close of installation of offshore piles (www.4coffshore.com).

A vessel used for installation of piles for offshore wind turbines (www.cape-holland.com).

Main activities: The project seeks to develop a method for accurate driveability predictions based primarily on theoretical considerations and back-calculation of driving logs from real-life installation of piles for offshore wind. The method will be based on existing methods, which are validated and subsequently modified through calibration:

- Assess state-of-the-art research and methodology within the area of offshore driveability and understand the basic physical and theoretical principles involved in the driving of large-diameter piles.
- Based on available driving data from installed piles, complete back-calculation in order to validate existing methods.
- Based on existing methods and available data for back-calculation, develop a theoretically founded method for robust and accurate driveability predictions for various ground conditions.

Contact persons: Martin Underlin Østergaard (muoe@cowi.dk), Søren Dam Nielsen

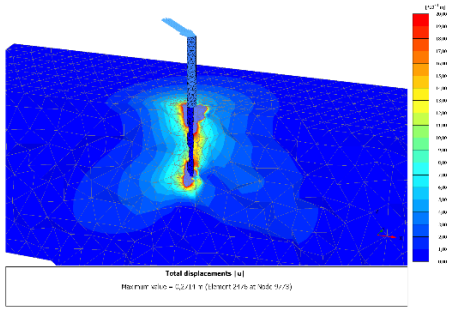
Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Dynamic analysis of monopiles for offshore wind

A project with COWI

Purpose: When designing foundation structures for offshore wind turbines, the dynamic performance of the structure, regularly characterized by the eigenfrequency, is often driving the design due to fatigue loading. Through measurements on foundation structures, e.g. monopiles, with operating wind turbines, it is possible to assess the dynamic performance and compare to the design. In order to optimize the design of a monopile, the dynamic performance must be estimated as close to reality as possible. The dynamic performance is strongly influenced by the stiffness of the pile-soil interaction; hence, the ability to predict the correct pile-soil stiffness for use in dynamic analyses is paramount.

Installation of a wind turbine on a monopile (www.4coffshore.com).



Finite element modelling of a monopile.

Main activities: The project seeks to improve existing and develop new methods for estimating pile-soil stiffness for use in dynamic analyses through theoretical considerations and back-calculation of real-life measurements, ultimately developing a robust model for estimating the eigenfrequency of the as-built monopile:

- Understand the basic physical and theoretical principles involved in the estimation of eigenfrequencies for monopiles.
- Develop a simple model to assess the eigenfrequency to understand and quantify the impact of the pile-soil stiffness.
- Based on available data from installed offshore wind farms, complete back-calculation using available 1D methods for estimating pile-soil stiffness and if possible improve existing or develop new methods for this purpose.
- Using finite element modelling, estimate the dynamic performance and compare to examined 1D methods and in-situ measurements.

Contact persons: Martin Underlin Østergaard (muoe@cowi.com), Søren Dam Nielsen

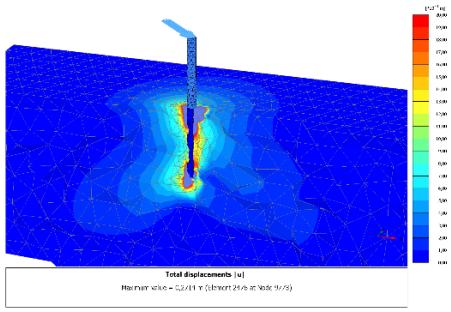
Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Development of best practice for finite element modelling of monopiles for offshore wind

A project with COWI

Purpose: Due to a strong demand for optimization of the foundation structures for offshore wind turbines, new tools are incorporated in the design process, and finite element (FE) modelling has become increasingly important. As for all FE models, the quality of the output is dependent solely on the quality of the input and the model setup. Since the use of FE modelling for offshore wind is relatively new, a so called "best practice" has not yet been developed. However, the recent investigations done in connection to the DONG-led PISA-project has provided a useful basis for developing best practices.

Sketch drawing of a monopile.



Finite element modelling of a monopile.

Main activities: The project aims at developing a best practice for FE modelling of foundation structures for offshore wind through considerations regarding theoretical soil behaviour and available constitutive models as well sensitivity analyses of input:

- Understand and establish the basic parameters for FE modeling of foundations as well as the individual importance of these.
- Develop FE model and compare total pile response to that obtained from simpler models, e.g. Winkler-models using various p-y formulations.
- Compare FE model to pile load test results and perform calibration and assessment of chosen constitutive model.
- Based on assessment of suitability of various constitutive models as well as elasticity of input parameters and experience regarding model setup, develop a best practice for FE modelling of offshore foundation structures.

Contact persons: Martin Underlin Østergaard (muoe@cowi.com), Søren Dam Nielsen

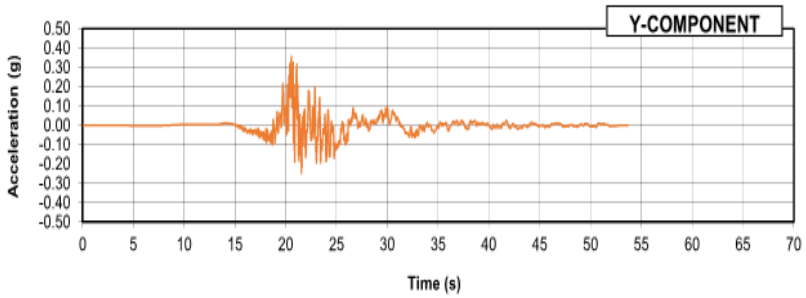
Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Earthquake design of monopiles

A project with COWI

Purpose: The offshore wind farms are moving to new regions, and new design scenarios are continuously introduced due to shifts in environmental climate and loading. Especially the Asian market for offshore wind is growing rapidly and natural hazards, like earthquakes, need to be accounted for to a much greater extent compared to e.g. European wind farms. Depending on the soil conditions, an earthquake can have a large impact on the structure, through e.g. liquefaction of the supporting soil and kinematic soil-structure interactions. This impact needs to be accounted for in the design.

Sketch of a monopile.



Example of acceleration time series from earthquake.

Main activities: The project aims at investigating available methods for aiding the design of monopiles for the offshore wind industry placed in regions with frequently occurring earthquakes. The following items can be considered in this investigation:

- Understand the concept of soil liquefaction and other earthquake-induced impacts on design of monopiles.
- Conduct literature review and develop a state-of-the-art of existing methods (e.g. based on p-y springs) for accounting for liquefied soil in design of laterally loaded piles.
- Develop a Winkler-based tool to assess the impact of different methods for accounting for liquefied soil.
- Using commercial software, like e.g. PLAXIS, FLAC or LPILE, conduct an assessment of the laterally loaded pile accounting for relative deformation between soil and pile caused by movement of the soil volume.

Contact persons: Martin Underlin Østergaard (muoe@cowi.dk), Søren Dam Nielsen

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Offshore wind suction bucket on an industrial scale

Universal Foundation

SIEMENS Gamesa
RENEWABLE ENERGY

Purpose: The project aims to develop a modular suction bucket design to the Siemens jacket concept for a +10 MW turbine. Objectives have been to create a modular bucket where modules can be produced in existing industrial manufacturing facility. In this project the aim is to demonstrate install-ability and in-place capabilities of design in laboratory environment.

Foundation costs of offshore wind including production and installation represent 20-30% of the total costs of deploying an offshore wind park. Lowering costs of foundations is a key element to lower the total Levelized Cost of Energy (LCoE) for offshore wind. Suction buckets are one of the most promising seabed interfaces technologies in the industry.

Siemens Jacket concept for +10 MW wind turbine.

Main activities: The project will focus on developing a working framework for the design of suction anchors used for the offshore wind industry, covering subjects such as, but not limited to:

- Installation of suction anchors using pressure and the challenges associated with this in various types of soil.
- The tensile and compressive capacity considering loading direction, loading rate and cyclic loading that are comparable to an offshore storm event.
- Laboratory testing to assess the impact of various types of loading (e.g. cyclic) to a typical offshore soil and the soil mechanics involved.
- Small-scale testing to assess the behaviour of the suction caisson/anchor during different loading and soil conditions.

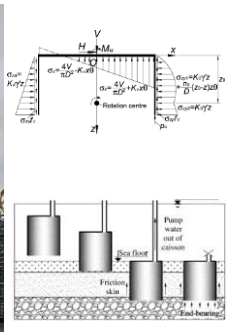
The Project will be in close corporation with Siemens Wind Power and Universal Foundation A/S

Contact persons: Lars Bo Ibsen (lbi@civil.aau.dk)

Theory: ☒☒☒ **Experimental work:**. ☒☒☐ **Computer modelling:** ☒☒☐

Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Analysis of installation and bearing capacity of a suction caisson used as a base of an offshore wind turbine supporting structure



Purpose: To develop a simple tool for preliminary assessment of installation and capacity of a suction caisson used as a support of a jacket type of offshore wind turbine foundation.

Traditional way of installation of offshore wind turbine foundations, be it a monopile or a jacket, is driving piles into the seabed by large hydraulic hammers. The operation is time consuming and is associated with generation of noise that might be harmful to the ocean fauna. Furthermore, piling is not always available depending on ground conditions of the seabed. Application of suction caissons appeared to be an attractive solution to piles, especially for a jacket type of foundations. Designing a complete suction caisson is a complex process and sophisticated tools are used for predicting installation and operational in-place capacity. Typically, there are no resources and/or complete data to perform such a task at an early stage of design. Concept developers desire a simple tool for approximate assessment of feasibility and required size of a suction caisson.

Main activities: Based on detailed FE (or alike) simulations, an analysis of installation and bearing capacity of a suction caisson constituting a part of a jacket type of offshore wind turbine foundation will be perform. Simulations shall be conducted for typical soils suitable for application of a suction caisson. Analysis of results will be used to formulate a simplified rule for assessment of desired size of a suction caisson. The simplified formulation is anticipated to take into account magnitude of wind and wave loads, topology of the supporting structure and soil properties. Through a comparison of the suggested methodology with detailed analyses a degree of accuracy shall be evaluated. The tool shall be available in form of a piece of software.

The tool may be validated against results of the full scale tests performed by Vattenfall.

Formulation of the simplified tool may be accompanied by (or even fully based on) a novel soil-structure-interaction methodology that will prove to be less time consuming and/or more accurate than present standard methods.

Contact persons: Lars Bo Ibsen, Søren Dam Nielsen

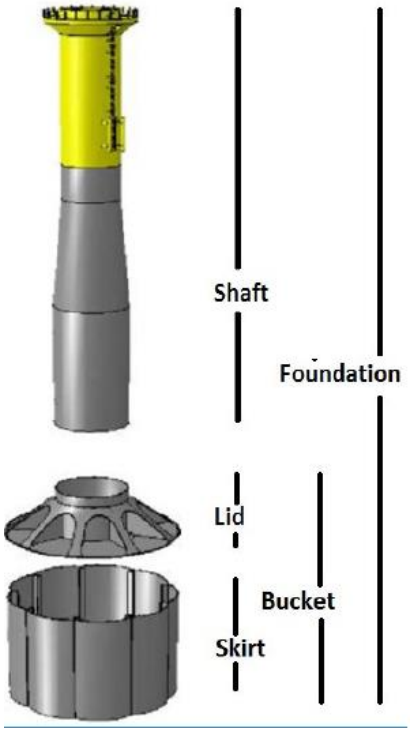
Theory: ☒☒☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Develop a new mono – bucket for a +10 MW wind turbine

Purpose: The project aims to develop a modular mono bucket design for a +10 MW turbine. Objectives are:

1. Create a modular bucket where modules can be produced in existing industrial manufacturing.
2. Demonstrate install-ability and in-place capabilities of design in laboratory environment.

Foundation costs of offshore wind including production and installation represent 20-30% of the total costs of deploying an offshore wind park. Lowering costs of foundations is a key element to lower the total Levelized Cost of Energy (LCoE) for offshore wind. Suction buckets are one of the most promising seabed interfaces technologies in the industry.



Main activities: The project will focus on developing a working framework for the design of the mono bucket used for the offshore wind industry covering subjects such as, but not limited to:

Installation of suction anchors using pressure and the challenges associated with this in various types of soil.

Bearing capacity considering loading direction, loading rate and cyclic loading that are comparable to an offshore storm event.

Laboratory testing to assess the impact of various types of loading (e.g. cyclic) to a typical offshore soil and the soil mechanics involved.

Small-scale testing to assess the behaviour of the mono bucket during different loading and soil conditions.

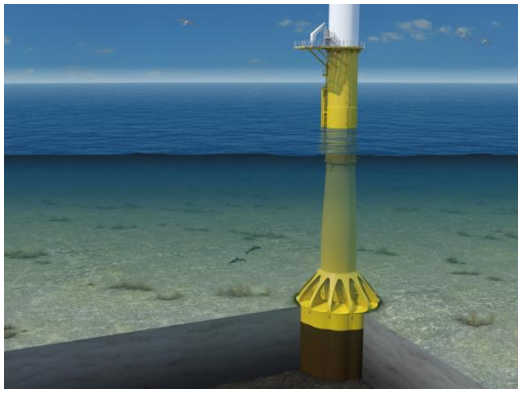
The Project will be in close corporation with Universal Foundation.
Contact persons: Lars Bo Ibsen (lbi@civil.aau.dk)

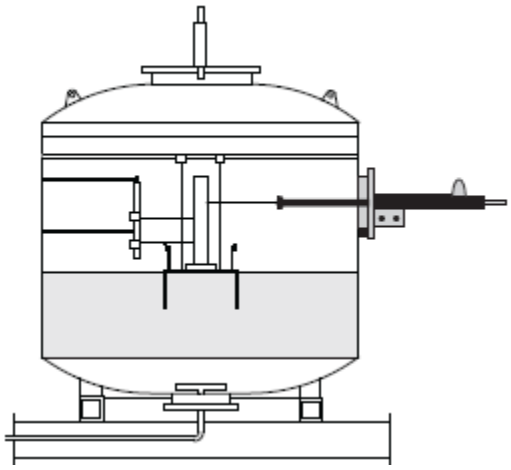
Theory: ☒☒☒ **Experimental work:**. ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): 3rd sem ☒ short master: ☒ Long master ☒

Cyclic Behaviour of Offshore Foundations

Universal Foundation

Purpose: Offshore structures are exposed to cyclic loading, mainly from wind and waves. Therefore, the soil surrounding the foundation will experience cyclic loading as well. Cyclic foundation behaviour is very complex and both strength and deformation parameters may change with cyclic loading. How they change depends on the nature of the cyclic load in terms of: load frequency, load amplitude and mean value. Even though research on the field has been carried out for the last 20 years, there is still no standardised guideline on how to predict the foundation response from cyclic loading.





Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

- Literature study on foundation behaviour due to cyclic loading.
- Performing cyclic model tests in the pressure tank.
- Calibrate one or more existing models to predict cyclic load effects.
- Develop new models to predict cyclic load effects.

The Project will be in close corporation with Universal Foundation.

Contact persons: Lars Bo Ibsen
Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☒

COWI

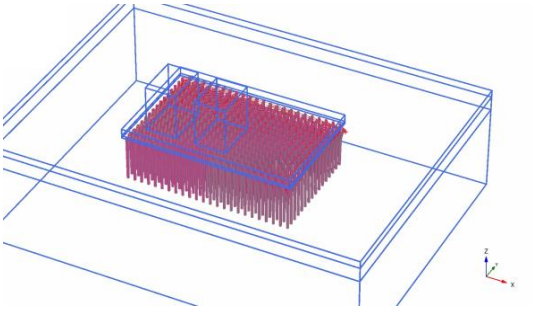
Design of pile foundation under dynamic loading

Purpose: The purpose is to assess the size of deformation during dynamic/quasistatic loading of a test stand founded on piles.

During testing of blades for wind turbines, the foundation is under a test plint exposed to significant dynamic/quasistatic loading. The size of the deformation of the foundation is of significant importance, since large deformations are not structurally acceptable.

In collaboration with a company performing the above-mentioned tests, the objective of the project is the determine the size of the deformations during test. Damping in the structure as well as the soil and piles under the foundation should be considered through a numerical model, for example in Plaxis 3D.

The output from the numerical model should be compared and calibrated with full-size measurements of the foundation during loading.



Main activities: The project will contribute to the knowledge of dynamically loaded foundation on piles. The activities will include:

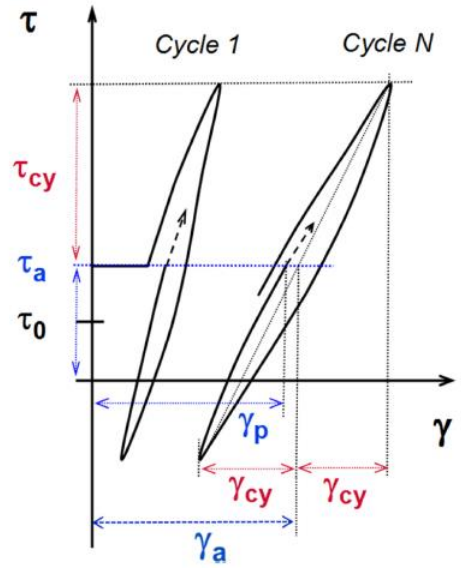
- Assess the state-of-the-art research and methodology within the area of dynamically loaded foundation on piles
- Numerical modelling of the dynamic loading of a fatigue test of the wind turbine blade.
- Programming the needed additional code for the numerical tool
- Comparison of full-size displacement measurement with the calculated numerical displacements.

Contact persons: Søren Dam Nielsen, (Kristoffer Lauridsen, krlr@cowi.com)

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Cyclic Behaviour of Soil

Purpose: Offshore structures are exposed to cyclic loading, mainly from wind and waves. Therefore, the soil surrounding the foundation will experience cyclic loading as well. Cyclic soil behaviour is very complex and both strength and deformation parameters may change with cyclic loading. How they change depends on the nature of the cyclic load in terms of: load frequency, load amplitude and mean value. Even though research on the field has been carried out for the last 20 years, there is still no standardised guideline on how to predict the soil response from cyclic loading.



Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

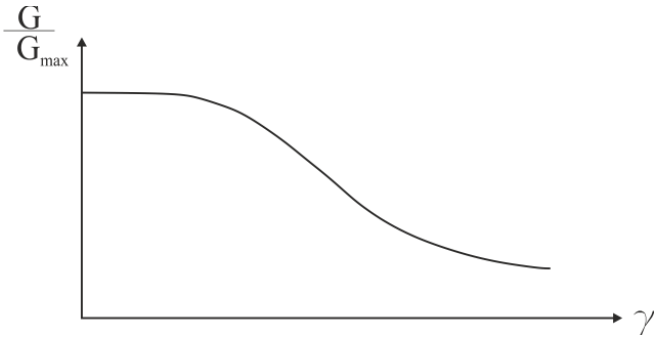
- Literature study on soil behaviour due to cyclic loading.
- Understanding how soil reacts to cyclic loading
- Performing cyclic triaxial tests.
- Calibrate one or more existing models to predict cyclic load effects.

Contact persons: Søren Dam Nielsen, Benjaminn N. Nielsen

Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☐☐
Suitable project type(s): 3rd sem ☐ short master: ☐ Long master ☒

Determination of small-strain stiffness of soils

Purpose: In the design of some geotechnical structures, such as large diameter monopiles, a correct estimation of the soil stiffness is of high importance. However, soil stiffness is both dependant on the strain and stress level. For dynamic loading and for determination of a geotechnical structures natural frequency, the soil experiences very small strain-levels. Hence, the small-strain shear Modulus is a key-parameter in design. By using Bender elements, it is possible to determine the small-strain shear modulus.



Even though, a bender element test is a very simple test to perform, the analysis of the measured data can be relative complex. The main activity of this study could be:

Main activities:

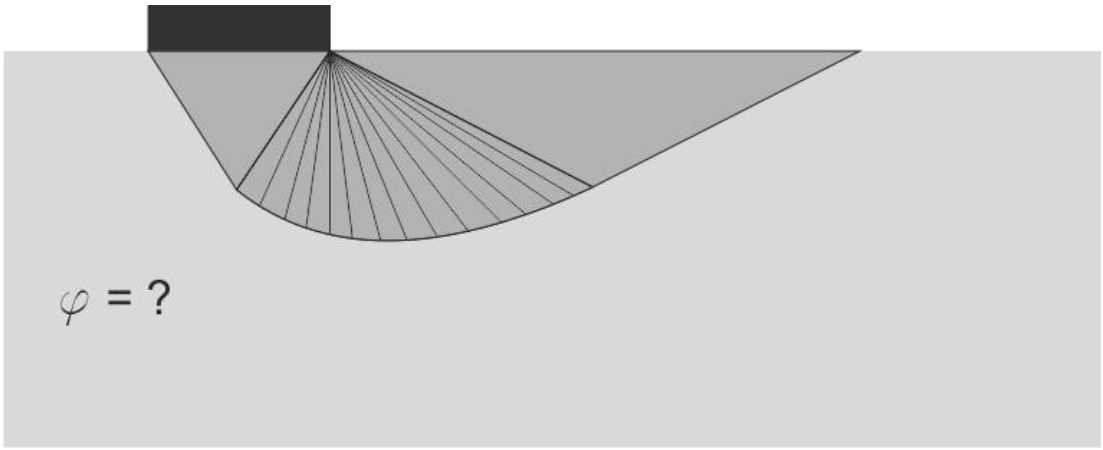
- Understand the bender element system
- Understand basic soil dynamics
- Investigate interpretation methods
- Investigate the effect of a more precise determination of G_{max}

Contact persons: Søren Dam Nielsen, Benjamin N. Nielsen

Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Statistical determination of geotechnical design parameters

Purpose: The (maybe) most important task for a geotechnical engineer is to determine representative soil parameters. Usually, a cautious estimate is considered as a good value. But, a cautious estimate is very dependant on the person, who interpret test data. Hence, design standards, such as Eurocodes and DNVGL, are working on a reliability based method, where a statistical approach is used to estimate representative soil properties.



The main activities in this project, is to understand how to apply a statistical approach to determine soil parameters and how this is used in foundation design.

Main activities:

- State of the art study
- Case study of soil parameters
- Different foundation solutions

Contact persons:
John Dalsgaard Sørensen, Benjaminn Nordahl Nielsen, Søren Dam Nielsen

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Alternative materials for 3. Limfjord crossing

Purpose: One of the major challenges in connection with the construction of a 3. Limfjord crossing is the lack of suitable materials for highway building.

Normally are used large quantities of sand and gravel to such a project. However, these materials are no longer available in the desired quantities in North Jutland. Therefore, there is a need for alternatives to the traditional materials and methods of hignway building.

Main activities: The project is relatively open with concern to the problem to be analysed and can include:

- State of the art study
- Case study of soil parameters
- Different foundation solutions
- Laboratory Tests

Contact persons: Benjaminn Nordahl Nielsen, Søren Dam Nielsen

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Aalborg Clay or other Danish clays

Purpose: To improve the knowledge about soil parameters for Danish soils.

In connection with the "Musikhus Kvarteret" a number of borings have been performed taking undisturbed samples in "Aalborg Clay" for laboratory testing in this project. CPT's and in situ testing make it possible to setup new interpretations of soil parameters.

Main activities: The project will contribute to the ongoing understanding of Danish soils.

The activities will include:

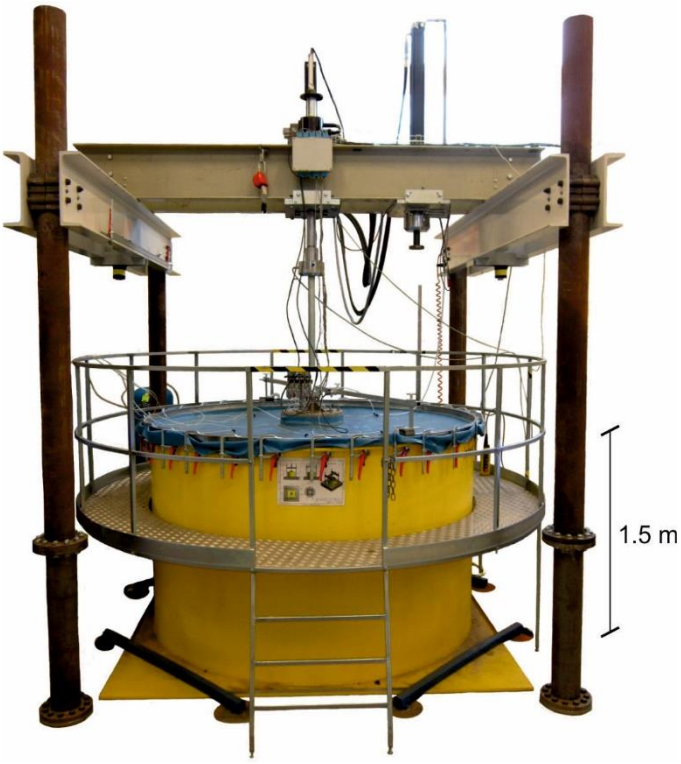
- Consolidation tests
- Triaxial tests
- Bender tests
- Using CPT and in situ testing
- Theoretical assessment

Contact persons: Benjaminn Nordahl Nielsen, Søren D. Nielsen

Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☐☐
Suitable project type(s): **3rd sem** ☐ **short master:** ☐ **Long master** ☒

Design of indoor test facilities

Purpose: Take part in designing our new indoor test facility/sandbox that will be used for model testing.



Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

- State of the art
- Boundary conditions
- Sand behaviour at low stress levels
- How to control the water level
- How to prepare and compact the sand in the box
- Numerical models of which foundations models that could be examined in the sand box

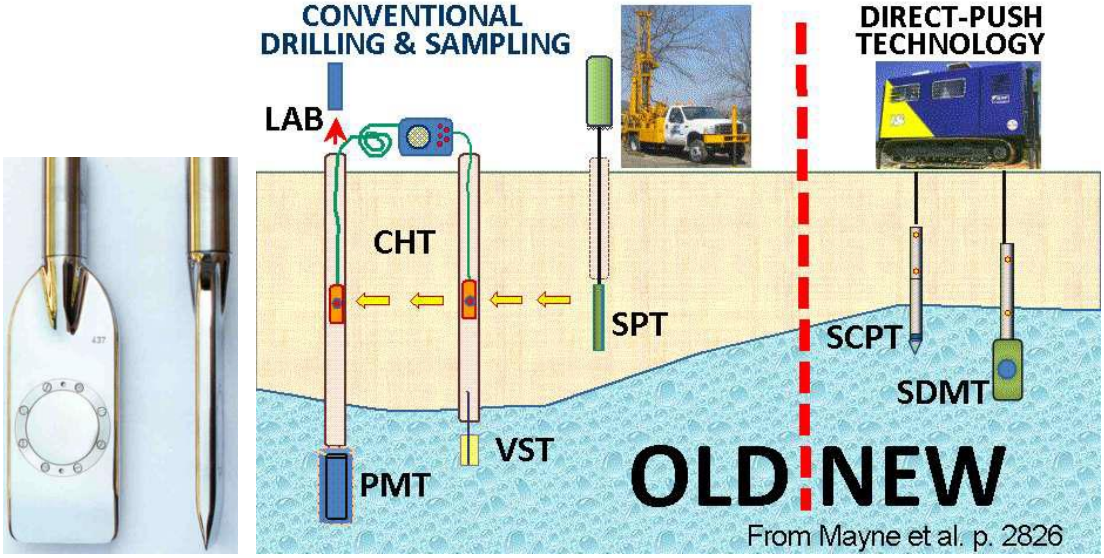
Contact persons: Lars Bo Ibsen, Benjaminn Nordahl Nielsen

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Rock the soil: SDMT Flat Dilatometer

Purpose: Try the new in-situ soil testing. The SDMT (seismic) Flat Dilatometer offers measuring / interpretation of a series of soil parameters by direct-push technology (M, c_u, K_o, OCR, φ, γ).

Aalborg University has the first SDMT equipment in Denmark.



Main activities: The project will contribute to the introduction of the DMT and SDMT technology in Danish soils. The activities will include:

- Setup of equipment
- Interpretation of data
- Field and laboratory Tests
- Theoretical assessment
- Best practise.

It may be possible to perform experimental field tests together with external company.

Contact persons: Benjaminn Nordahl Nielsen, Lars Bo Ibsen

Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☐☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

CPT based soil strength correlations

Purpose: Contribute to the geotechnical society by developing new approaches to determine soil strength parameters from CPT.

Today the Cone Penetration Test (CPT) is increasingly being applied to geotechnical projects. Still, there exist no uniform methods on how to interpret strength parameters from the CPT measurements. Aalborg University has CPT rig which makes it possible to conduct CPTs and collect undisturbed soil samples at places where it is impossible for other boring rigs.
Watch the CPT rig at https://www.youtube.com/watch?v=zf_eRpbo1C0

Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

- State of the art study
- Setup of equipment
- Field and laboratory Tests
- Interpretation of data
- Theoretical assessment

Contact persons: Lars Bo Ibsen, Benjaminn Nordahl Nielsen, Søren D. Nielsen

Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☐☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

New method for soil compaction

Purpose: To develop new methods for compacting sand in the laboratory and possibly also the field.

Currently, different methods are used for compaction of sands. In the laboratory e_{max} and e_{min} (Relative density) is measured using a stamping method, and for model testing the soil is being compacted using rod vibrators, giving a possibly variating compaction. In the field, sand is compacted using a vibrating plate compactor. All methods however are time-consuming since they are performed manual.

Main activities: The project is relatively open with concern to the problem to be analysed and can include:

- State of the art study
- Laboratory Tests
- Field testing
- Reliability
- Design model creation / best practise.

It may be possible to co-operate with Department of Mechanical and Manufacturing Engineering as regards to designing a robot that are able to perform the compaction.

Contact persons: Benjaminn Nordahl Nielsen, Lars Bo Ibsen
Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Experimental study of the interface strength between construction materials and soils

Purpose: For many geotechnical structures, the strength of the soil-structure interface is vital for the design. Examples of structures, where this is a key-factor is axially loaded pile foundations and suction caissons, for sliding resistance of for example anchor blocks for suspension bridges. Despite the significant importance of the interface strength to the foundation design, the geotechnical society still miss guidelines on how to model the soil-structure interface.

The main goal of this project is to investigate the soil-structure interface strength experimentally. Investigations can be executed as pull-out tests or sliding tests of structures of various materials and soil types. The project can also include both numerical and analytical solutions of simple problems to develop guidelines on how to model the soil-structure interaction.

Main activities: This project could be solely experimental or combined with numerical work. The main activities of the project could be:

- Laboratory testing
- Numerical modelling
- Comparison of laboratory tests to finite element programs

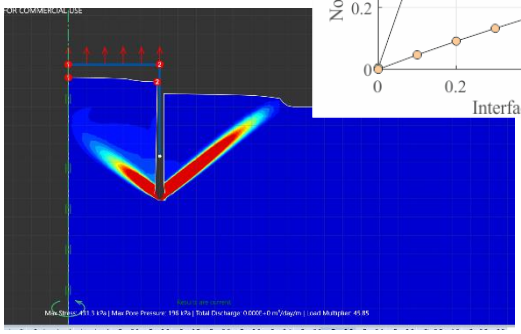
Contact persons: Søren Dam Nielsen, Benjaminn Nordahl Nielsen

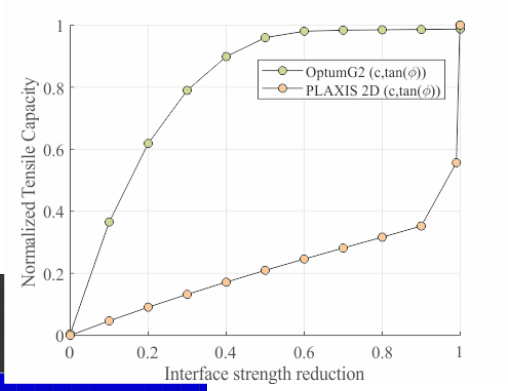
Theory: ☒☐☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☐☐☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☒

Numerical study of the interface strength between construction materials and soils

Purpose: For many geotechnical structures, the strength of the soil-structure interface is vital for the design. Examples of structures, where this is a key-factor is axially loaded pile foundations and suction caissons, for sliding resistance of for example anchor blocks for suspension bridges. Commercial Finite Element softwares, such as PLAXIS and Optum, model the soil-structure interface differently. Despite the significant importance of the interface strength to the foundation design, the geotechnical society still miss guidelines on how to model the soil-structure interface.

The main goal of this project is to investigate the soil-structure interface strength numerically. Investigations can include how the interface strength is modelled in different programs and how this affects the final outcome.





Main activities: This project could be solely numerical or can be combined with experimental work. The main activities of the project could be:

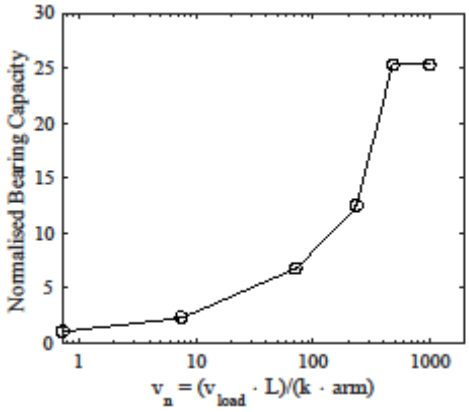
- Numerical modelling
- Comparison of finite element programs
- Laboratory testing

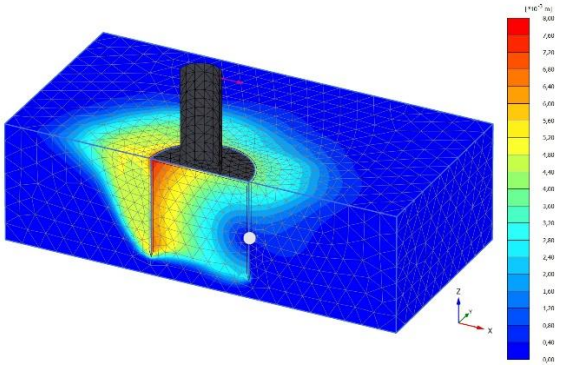
Contact persons: Søren Dam Nielsen, Benjaminn Nordahl Nielsen

Theory: ☒☐☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☒

Investigation of partly undrained soil behaviour using Finite Element Modelling.

Purpose: For many geotechnical structures the ULS design often consider sand as a drained material and clay as an undrained material. However, for offshore structures the load duration is so short partly- of fully undrained response is present in sandy soils. For some structures, such as the bucket foundation, this will lead to the generation of negative excess pore pressure, which increases the ultimate capacity of the foundation. This effect has been proven by model testing. The aim of this project is to investigate whether it is possible to simulate these effects by commercial finite element programs, such as Plaxis 3D.





Main activities: The main activities of the project will include the drained, partly and fully undrained soil behaviour and simulations hereof in Finite element programs, such as Plaxis 3D.

- Study of drained, partly- and fully undrained soil behaviour.
- Numerical modelling
- Comparison with existing laboratory results

Contact persons: Lars Bo Ibsen, Søren Dam Nielsen,

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☒

Designing climate roads

Purpose: Understanding climate changes impact on roads and investigate how future roads can be designed.

Main activities: The project is relatively open with concern to the problem to be analysed and can include:

- State of the art study
- Laboratory Tests
- Field testing
- Reliability
- Design model creation / best practise.

Contact persons:
Benjaminn Nordahl Nielsen, Søren Dam Nielsen

Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☐☐☐
Suitable project type(s): 3rd sem ☒ short master: ☒ Long master ☒

Comparison between PLAXIS 3D and OptumG3

The project is in cooperation with Subsea7 (Christian Olsen) and could be chosen as a company stay on 9th semester.

Purpose: A new software is available for determination of ultimate capacity of foundations with use of lower and upper bound finite element limit analysis (FELA) in 3D, OptumG3. The conventional approach is the use of finite element analysis where the full load displacement curve is determined to assess the ultimate capacity.

Subsea 7 have on some occasions experienced large discrepancies between PLAXIS 3D and OptumG3 for torsional loaded foundations on sand and sand overlaying very soft clay.

The purpose of the thesis is to assess the foundations, understand the numerical background of both PLAXIS 3D and OptumG3 and determine the origin of the differences in ultimate capacity.

Main activities: The project will contribute to the best practice engineering at Subsea 7 to choose the tool with best accuracy to determine ultimate capacity. The contents for the thesis:

- Description of the cases analyzed
- Thorough review of the theory behind PLAXIS 3D and OptumG3.
- Sensitivity study of the cases in PLAXIS 3D and OptumG3
- Determined the origin of the difference between the software packages.

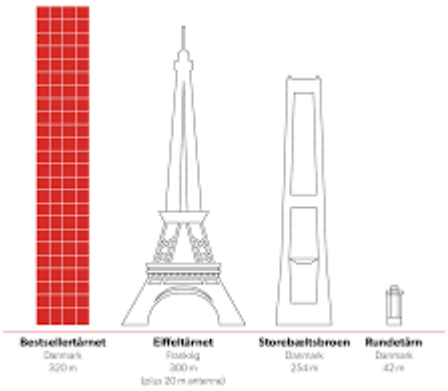
Contact persons Subsea7: Christian Olsen
Contact persons AAU: Søren Dam Nielsen, Benjaminn Nordahl Nielsen

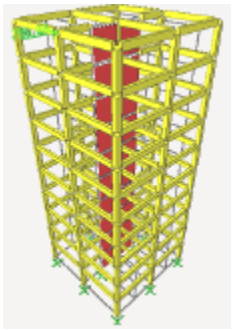
Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

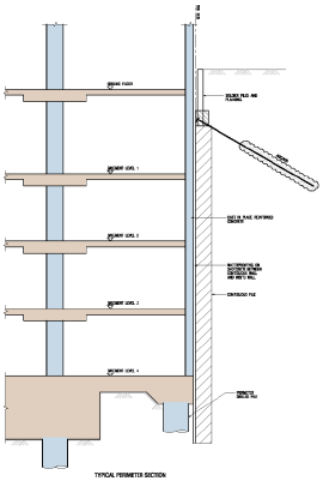
Frontiers in building skyscrapers

Purpose: Designing skyscrapers or towers mean cutting edge challenges in connection with every discipline within Civil Engineering and especially design for Stability and foundation of the construction.

I Brande they are gowing to build the Bestceller tower. A building with a hight of 325 m. Right now the engineerins are starting the design. I is expected that even higher building will be the new term all over Denmark and in Europe. In this project you have the oppertunity to investigate the challenges of building these landmarks.







Main activities: The project is relatively open with concern to the problem to be analysed and can include:

- State of the art study
- Case study of foundation solutions
- Numerical modelling
- Laboratory Tests

Contact persons: Benjaminn Nordahl Nielsen, Søren Dam Nielsen

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Suitable project type(s): 3rd sem ☒ short master: ☒ Long master ☐

Risk-informed decisions for up-classification of existing bridges

Purpose: The purpose is to develop a framework for risk-informed decision support, when existing bridges need to be up-classified to allow for passage of larger trucks, than they were originally designed for.

Bridges are designed to meet certain classes, which determines how large special truck that are allowed to pass the bridge. Often, large trucks need to find alternative routes, if the classification of bridges of the nearest route is insufficient. However, although the bridges were originally designed to have a lower capacity, it might have larger capacity than assumed in the design. Tests such as proof loading and material testing can be performed to reduce uncertainties of the bearing capacity, and an up-classification might be possible, without any strengthening. However, proof loading is expensive, and there is a risk that the bridge might collapse during the test, therefore cheaper tests might be preferable, although less accurate. To provide rational decision support for those decisions, a risk-informed decision framework can be made for testing of existing bridges considering e.g. costs of material testing, costs of proof loading, costs of advanced modelling, and risk of failure during proof loading.

Main activities:

- Reliability analysis of existing bridges
- Reliability updating using proof loading and material testing
- Inclusion of advanced nonlinear models through e.g. response surfaces
- Formulation of cost models
- Development of decision framework based on the Bayesian decision theory

The project will be performed in collaboration with COWI.

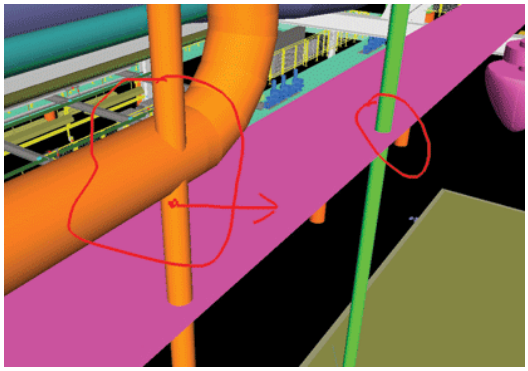
Contact persons: John Dalsgaard Sørensen, Jannie Sønderkær Nielsen

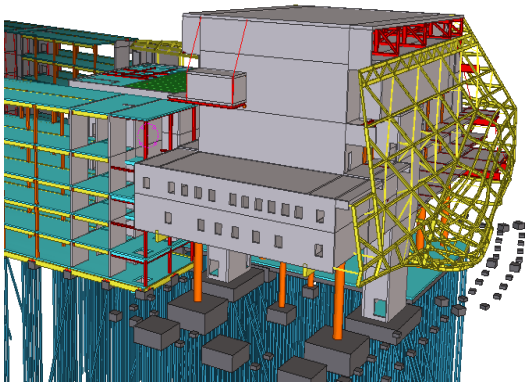
Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Structural modelling and design coordination

Purpose: The construction industry is changing from traditional CAD drawings to more intelligent 3D object based models of the entire building. There are many attempts to improve the structural design process by making a better connection between object based CAD systems and structural simulation tools. The simulation tools can be more or less integrated with specific CAD systems or they may exchange data through open international standards. An important issue for the structural engineer is also the often complicated coordination with requirements from other disciplines such as architecture, HVAC etc. New IT tools are introduced to assist this coordination.

The purpose of this project is to identify critical elements of the integrated design and coordination process and examine how new methods and information technology can assist us in the future construction industry.





Main activities:

- Identify strength and limitations in current practices and identify opportunities with upcoming technologies in the area
- Review of enabling Information and Communication technologies (ICT), including software, data models, international standards, and human computer interaction tools
- Examine today's possibilities with existing tools
- Identify needs for new ways of working and from that derive a list of requirements on technical solutions
- Demonstrate possible solutions for the near future and describe issues for future development

The work may be in collaboration with a consulting engineering company.

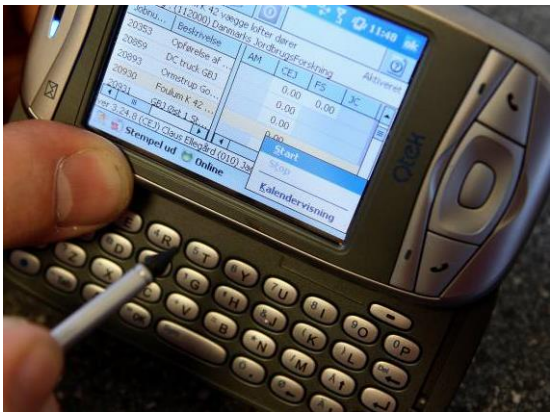
Contact persons: Kjeld Svidt

Theory: ☒☒☐ **Experimental Work:** ☒☒☐ **Computer Modelling:** ☒☒☐

Future information technology at the construction site

Purpose: In recent years, the construction industry has started changing from traditional 2D CAD drawings to more intelligent 3D object based models of the entire building. Such models give us a number of new possibilities for planning and controlling the activities at the construction site through advanced 4D models and possible links between the physical construction components and the virtual building model. New information and communication technology can improve the communication of correct instructions at the right time for the construction work as well as capturing information for quality assurance and as-built documentation.

The purpose of this project is to identify important problems within the area and propose solutions for future use of state-of-the-art information technology at the construction site.



Main activities:

- Identify current practices and problems in traditional construction projects
- Review of enabling technologies, software, hardware, international initiatives
- Test existing methods, software, hardware
- Identify needs and requirements for new solutions
- Build early prototypes with more or less functionality for initial tests

The work may be carried out in collaboration with a construction company.

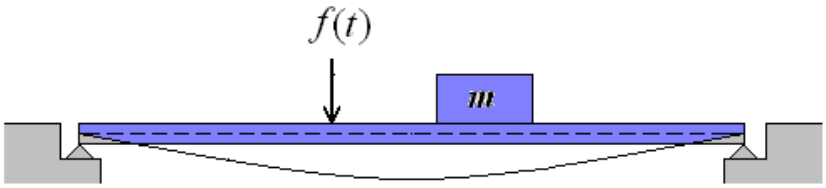
Contact persons: Kjeld Svidt

Theory: ☒☒☐ **Experimental Work:** ☒☒☐ **Computer Modelling:** ☒☒☐

Dynamic human-structure interaction

Background: In static calculus, passive (sitting/standing) humans are modelled as a rigid mass attached to the structure. In dynamics, humans in motion (people walking or jumping) are modelled as a dynamic load bringing the supporting structure into vibration.

Human in motion Passive person



In assessments of vibration levels of slender structures carrying humans (such as footbridges, stadia-structures, or office floors) these models are conventionally employed. But are they reasonable?

Purpose: The aim of the project is to study mechanisms of human-structure interaction focusing on areas where the models mentioned above are inadequate. Prior to codifying new models describing the phenomena, they need to be properly researched.

In the project you will plan and conduct experiments striving to highlight the true mechanisms of human-structure interaction on slender structures. Measured vibration data will allow you to calibrate alternative models of the interaction accounting for the flaws in existing models.

Implications of findings (new models of the interaction) you may illustrate through computer simulations of structural response to the dynamic loads generated by humans.

Contact person: Lars Pedersen

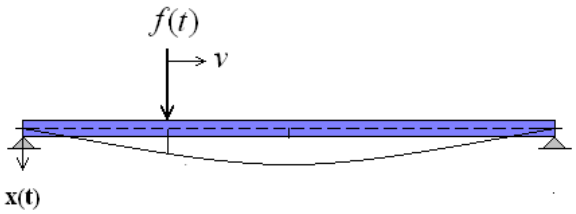
Theory: ☒☐☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☐

Dynamic human loading and stochastic models for estimating structural responses

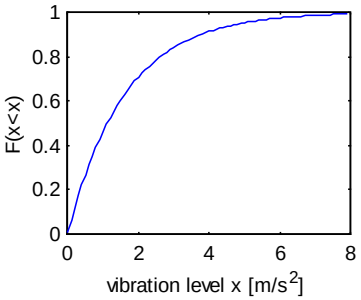
Background: Some civil structures are so slender that their modes of vibration may be excited by the basic frequency of human motion resulting in resonant structural action. The undesired resonant action may for instance occur in footbridges, stadia structures or in open-space office floors as a result of walking or jumping.

Codes and standards handle the phenomenon semi-empirically or even fully deterministic although fundamentally the loading generated by humans in motion is stochastic.

Purpose: The aim of the project is to develop and test stochastic models describing the loading and the structural response. An essential contribution would be to derive statistical distributions of structural responses to human-induced loading, as this would provide valuable information for assessing structural safety or serviceability. Specifically, the risk of exceeding various vibration levels is of interest although it is actually a parameter not given much/any focus in existing design codes.



Walking load when v > 0 m/s, "Jumping load " when v = 0 m/s



Statistical distribution of response

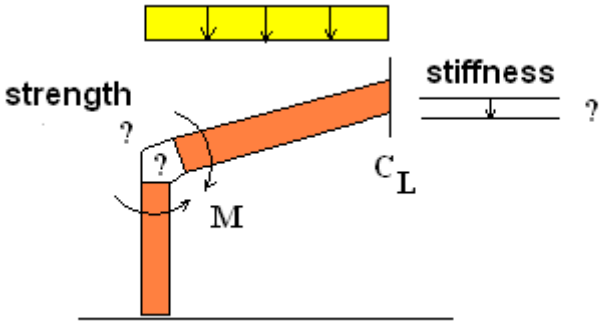
Through the project you will learn how to model the dynamic excitation of humans in motion, deterministically as well as stochastically. You will conduct parametric studies and numerical simulations to highlight essential implications of stochastic modelling of the phenomenon. Experimental verification of models is a possibility if so desired.

Contact persons: Lars Pedersen, Christian Frier

Theory: ☒☐☐ **Experimental works:** ☐☐☐ **Computer modelling:** ☒☒☒
(The amount of experimental work can be decided during the project)
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☐

The corner of laminated timber frames

Purpose: Laminated timber frames are, for instance, desirable in structures where the aesthetics of the structure is in focus. A weak point in a timber frame is the frame corner and its strength and stiffness. But perhaps the corner does not need be made of wood?



Could a reinforced concrete structure or a steel structure be employed in the corner instead? At least the drawbacks of a corner made of wood might be removed and by employing wood in the remaining part of the frame, the frame would still visually appear much like a full wooden frame.

Main activities: The aim of the project is to explore the stiffness and strength of a timber frame employing different solutions in the corner of the frame (steel and/or reinforced concrete and using the full timber frame as reference).

In the project you will develop numerical and analytical models for the various solutions and full-scale tests will be conducted aiming at verifying the strength and stiffness predicted by your models.

Should your investigations reveal that solutions with steel or reinforced concrete in the corner of the frame are feasible (in terms of strength and stiffness) it might indicate a potential for a new type of frame structures.

The project might involve co-operation with external parties having an interest in mapping the potential of alternative solutions for timber frames.

Contact persons: Lars Pedersen, Christian Frier

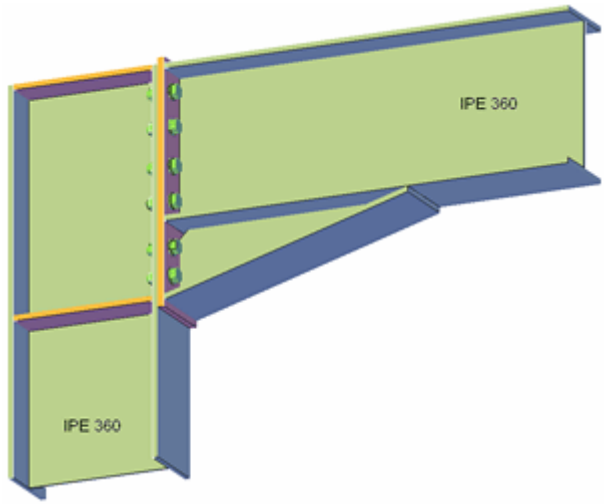
Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☐

Analysis of Joints in Steel Structures

Purpose: Joints in steel structures are frequently made using fasteners. These are not fully rigid which may play a role in terms of behaviour of the steel frame.

The purpose of the project is to investigate how flexibility in joints influences various global characteristics of the steel frame, and to study how Eurocode models these influences.

Another item of interest is to explore the load bearing capacity of joints made using fasteners (analytically, numerically, and experimentally) and to compare results with Eurocode models.



Main activities: The project is relatively open with concern to the problem to be analysed. However, in any case the activities will include:

- A mixture of analytical, numerical and experimental investigations
- Comparison of results with Eurocode models.

Contact persons: Lars Pedersen

Theory: ☒☒☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☐

Advanced Analysis of Steel Frames

Purpose: In ultimate limit state analyses of steel frames compression forces and bending moments are of concern, as they may lead to global instability manifested in either buckling or lateral torsion failure.

The design guide Eurocode sets up procedures for evaluating the ultimate limit state and actually, Eurocode (EC) suggests a number of different design approaches to choose from. Some EC-approaches are more simplifying than others, and this means that the final evaluation of the ultimate limit state depends on the method chosen for the evaluation. Or does it?

The purpose of the study is to highlight and quantify load carrying capacity of steel frames employing different methods, ranging from basic methods to more advanced methods (in all methods FE-analyses are required but to various degree of complexity).

In the initial part of the study, focus will be on analysing a reference steel frame, but in order to highlight the degree of differences in calculated load carrying capacities it is useful to extend the study. This, for instance, by studying a range of steel frame configurations or to conduct some other type of parameter study focusing on sensitivity of outcome of your calculations to input assumptions related to structural modelling.

Main activities: Besides, from a literature review focusing on the background for EC-guidance focus will be on

- Implementing and describing procedures
- Finite element modelling and analyses
- Parameter and sensitivity studies

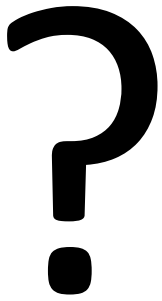
so as to provide an overview of load carrying capacities of steel frames as computed using different methods.

As part of the study it might be useful also to analyse one of the steel frames which recently collapsed due to heavy snow loads.

Contact persons: Lars Pedersen
Theory: ☒☐☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐

Your own idea

Purpose: The purpose of a masters thesis is to study a specific topic within Engineering. As it demands a lot of work, it is important the topic is of interest. Therefore, students are encouraged to come and present their own ideas for a masters thesis. The main activities can therefore include various tasks, whereof some are listed below.



Main activities:

- State of the art study
- Case study
- Numerical modelling
- Programming
- Laboratory testing
- Field tests
- Analysis of monitored data
- Combinations of above

Contact persons:
Who ever you think could be relevant

Theory: ??? **Experimental work:** ??? **Computer modelling:** ???
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

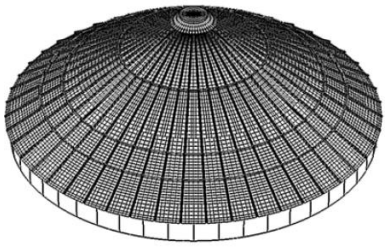
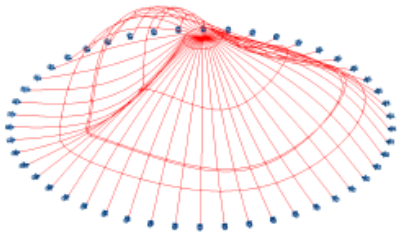
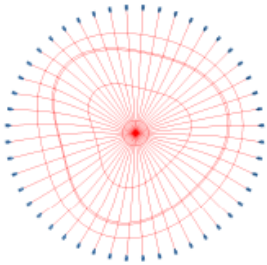
Example of company stay project

Analysis of snow-load induced damage on conical silo roof

Company: Cowi, Aalborg Office
Company type: Consulting engineering company
Webpage: www.cowi.dk, www.cowi.com
Location: Aalborg

In the winter of 2009/2010 heavy snowfalls occured in Northern Jutland in Denmark. The ensuing large snowloads caused several roof collapses throughout the region. Among these were the several roofs of silos for crop storage. Crop silo structures are typically composed of corrugated steel sheets stiffened by steel profiles.

The company wanted to perform a detailed analysis of these collapses to assess the cause(s), and this was chosen as a project for the student doing the company stay.

The structure was studied by means of finite element analysis, including non-linear effects such as bifurcation buckling, large displacements and plasticity. Also, different detail levels in the modelling were compared, as was beam and shell models.

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